Defense Technical Information Center Compilation Part Notice

ADP021347

TITLE: Intelligent Nodes for Course of Actions Analysis - Interpretability

DISTRIBUTION: Approved for public release, distribution unlimited

This paper is part of the following report:

TITLE: International Conference on Integration of Knowledge Intensive Multi-Agent Systems. KIMAS '03: Modeling, Exploration, and Engineering Held in Cambridge, MA on 30 September-October 4, 2003

To order the complete compilation report, use: ADA441198

The component part is provided here to allow users access to individually authored sections of proceedings, annals, symposia, etc. However, the component should be considered within the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP021346 thru ADP021468

Intelligent Nodes for Course of Actions Analysis - Interpretability

Edward Dawidowicz, *Member, IEEE*
US Army, Research and Development Engineering Center (RDEC)
Fort Monmouth, NJ 07703
Email: edward.dawidowicz@mail1.monmouth.army.mil

Abstract *The interpretability faculty is a vital element within the framework of Intelligent Systems [8]. Central to planning, Course of Action (COA) and Course of Action Analysis (COAA) emerge in the process of interpretability of heterogeneous information. The purpose of this paper is to discuss the interpretability mechanism that can be employed by computing machines to promote intelligent behavior.*

Keywords: Intelligent systems, multi-resolutional modeling, multi-dimensional modeling, situational calculus, dynamic planning, course of action, course of action analysis, semantic networks, entity-relational networks, natural language, cognitive systems, semiotics, distributed computing, knowledge-intensive, knowledge representation.

1. INTRODUCTION

The emergence of interpretability seems to have its roots in Situational Calculus [5] and relatively recently was introduced as an evolving branch of Modal Logic [11]. While logic provides a sound framework for implementation in computing devices it confines intelligent system modeling to an idealized world. Coping with a realistic world prompts a requirement of interpretation of information acquired by system's observation, experience and exchange with other entities. The interpretation or the act of interpretability requires a 'mechanical' framework within which such an act can be accomplished.

Intelligent Nodes [3] are multi-agent knowledge-intensive computational systems that provide user assistance by interpreting the flow of information and evaluate the relevance of such information to the events that are taking place or may take place in the near future. The information provides the stimulus for Intelligent Nodes and is analogous to the information we acquire through our multi-modal sensory suite consisting of olfactory, tactile, vision and other sensors. The content of information received is subject to interpretation resulting in contextual relevance of such information to the past, particular, and arising situations. The understanding of the situation emerges in the process of interpretability of sensory information as a relational model of self to the rest of the world.

Planning is essential process for the intelligent systems to achieve a given goal. The COA is initiated in attempt to envision an intermittent step in a plan i.e. form **n** to **n+1** state. Several COAs are generated that may lead to the attainment of that intermittent step. The COAA is used to select the 'best' from a set of potential COAs. The planning however is a complex multi-dimensional and multi-resolutional process as are the generation of COAs. The information that is used by Intelligent Nodes is frequently incomplete and ambiguous. The Intelligent Nodes must interpret such information and use hypothesis to assess its relevance towards particular situations. The hypothesis is COA while COAA is used to evaluate particular hypothesis for contextual relevance to a particular situation.

2. INTELLIGENCE

A process of interpretation is inseparable from something that we call intelligence. While the definition of intelligence is evasive and its formulation seems a futile effort some appropriate definition nevertheless is required to outline the scope of this discussion. The definition remains at large as researchers look for the definition within the confines of their fields of study while only a multidisciplinary approach seems to shed enough light to resolve this enigma. The term 'intelligent' is frequently used as a marketing ploy to attract a particular customer's attention. However in order for a

KIMAS 2003, October 1-3, 2003, Boston, MA, USA.

system to be intelligent it must possess certain faculties within the architecture that defines such a system. However before such architectural elements can be brought into a discussion at first one has to define what is expected of an intelligent system followed by a definition of intelligence.

2.1 Self Awareness -Self-awareness is defined as:

1. Awareness of a group, team, enemy, purpose and role of self
2. Awareness of the physical world
3. Awareness of:
   a) the physical self and abilities,
   b) how these abilities can act upon the physical world,
   c) contemplation of using these abilities to change the physical world via self actions and
   d) ability to produce actions able to influence states of the group, team and enemy.

This describes three main grounds of self-awareness: the social environment, the physical world, and the self [9]. All three must be considered in the process. The property of self-awareness is true for a single intelligent node and a group of nodes.

2.2 Intelligent Behavior - Intelligence is the ability of entities to deal with uncertain situations and achieve given goals, within the domains of their faculties. This intelligent behavior is revealed by the following actions:

1. Interpret sensory information and goals (external and internal to the system)
2. Distinguish objects and their properties
3. Determine spatial, functional and temporal relationships of object
4. Develop a set of plans of action, using relationships, by being focused on the given set of goals
5. Evaluate a developed set of plans and select the plan(s) best suited for achieving the goals
6. During execution continuously monitor the environment to determine if changes to the environment require changes to the plan under execution or other goals
7. Share relevant information and knowledge with the relevant entities

2.3 Defining Intelligence - The definition of intelligence is given to reflect Intelligent Nodes utility that in turn is mandated by requirements such as: timely dissemination of situation pertinent or contextual information, assist in collaborative planning, course of action generation and analysis.

Once the intelligent behavior is stated the intelligence can be defined as:

1. Ability to arrange objects in time and space for the purpose of achieving a given goal while dealing with uncertainties associated with interaction of these objects (analogous to course of action generation, course of action analysis and planning)
2. Ability to differentiate new objects from known objects (force-on-force ratios/patterns, potential ambush situations/vulnerabilities, and enemy deception...)
3. Form hypotheses as plausible interpretations and test hypotheses (Note: Hypotheses is analogous to course of action. Testing of hypotheses is an interpretive process and is done by simulation that is analogous to course of action analysis).
4. Abilities of (2) and (3) allow the emergence of learning.
5. Self-awareness (Common Relevant Operational Picture (CROP) and Situational Understanding (SU)).
6. Goal oriented (commander's intent, survivability, information requirements and etc....)
7. Ability to test hypotheses by means of simulation (grounding the 'logic' to the 'real world' or having the means to quantify the validity of a hypotheses)

This search for possible combinations by arranging objects in time and space, testing these combinations against the world model seems to reflect the observation that Umberto Eco makes: "We explore plurality of possibilia to find a suitable model for realia." [4].

2.4 Architectural elements - At least three architectural elements are essential to allow faculties of intelligence to emerge. The elements appear as the encompassing multiresolutional modeling theme, knowledge representation framework and contemplation or a simulation mechanism. Together these elements comprise an individual agent. Intelligent Nodes embody many of such agents. These agents exist in a hierarchical architecture to collaborate and share goal driven computational load. Further this collaboration and work sharing is true for the entire network of Intelligent Nodes.

Multi-resolutional modeling is natural and essential in constructing intelligent systems. An approach to decision-making process using multi-resolutional, multi-granular and multi-scalar schemas was emphasized and discussed in [7]. The Intelligent Nodes have at least five main levels of resolution. The five levels reflect military doctrine of self, two levels above the hierarchy and two subordinate levels. The number of level of resolution for a particular system is an optimization problem constrained by the processing speed of the system and required level of intelligent performance.

The Entity Relational Network (ERN) functions as computational infrastructure and knowledge representation storage. The concept of an entity relational model was introduced by P. Chen [2] and served as the foundation for developing relational databases. However, ERNs are much more than a relational technique of storing data. The ERNs serve as concept emerging structures that are continuously built using both previously processed and newly incoming information. The concept of ERNs coupled with multi-resolutional representation is instrumental in addressing interpretability problems faced by intelligent systems. A snapshot of an event is stored in ERN at time **t-1** to be compared with ERN at time **t**.

The differentia between the snapshots will be detected and interpreted by the system by developing hypotheses as to the meaning of such a variance. The hypotheses are tested using the multiresolutional internal representation of the world model. The testing is done within nested simulation loops such as Elementary Loops of Functioning (ELFs) [6] . This structure is similar to hierarchically intelligent machines concept [10].

3 INTERPRETABILITY

The necessity to simultaneously dwell on several intelligence constituent faculties within a multidisciplinary framework creates a difficulty in defining intelligence or intelligent behavior. Interpretability is one such faculty that sanctions intelligent behavior. This faculty is not a product, but a part of intelligence. Interpretation allows data to be transformed into contextually relevant information by searching for relationships information content to a particular situation. This search is a knowledge intensive process accomplished by a single or a group of Intelligent Nodes.

In general the system interprets:

1. Any input provided to the system
2. Any output (to adjust message semantics to the recipients ontology and within the anticipated context)
3. Messaging that flows between other functioning elements

Basic elements subject to interpretation are:

1. Mission focus (threat, goal, mission plan, commander's intent, etc.)
2. Set of known objects and situations
3. Set of anticipated objects and situations

Processes of interpretation:

a) Process input within the node by finding relationships between incoming information and anticipated situation
b) Relate input based on self-awareness and situational understanding for **t-1**, **t**, **t+1**.

Note that situational understanding is a product of interpretation using self-awareness.

3.1 Interpretation of Goal - A goal is an expected set of states that an entity is required to achieve as a result of completed actions. A goal or set of goals is interpreted to produce an execution plan(s). The interpretation of a commander's intent specifies a set of states that a system is required to achieve in order to arrive at the goal state. The commander's intent clearly specifies the goals to be achieved by the subordinate units and the constraints within which such undertaking should be accomplished. Commander's intent is to be interpreted by Intelligent Nodes to collaboratively produce a plan of actions focused on achieving the specified goals.

3.2 Natural Language - The bulk of messages containing information are written in natural language. It is acknowledged that computer understanding of natural language is instrumental in achieving reduction in manpower [1]. The product of this effort resulted in the development of the Battle Management Language [1](BML). The BML lexicon is small,

[1] BML is a implement that will give commanders and staffs direct interaction between standard Army Command, Control, Communications, Computers, and Intelligence (C4I) components and supporting the models and simulations that the Army uses to drive both testing and training on the C4I systems. Its vocabulary is derived from doctrinally sound military terms and graphics.

but a good starting point for Intelligent Nodes to evolve the capabilities required to achieve warfighter-computer linguistic interoperability.

The understanding of a natural language requires ability to interpret a message within the context of a particular situation or based on the situation of the originator of such a message. The formulation of the message requires understanding of the situation and interpretation of how such a message will be interpreted.

Allowing the computer to have natural language faculties can open critical opportunities not only in understanding warfighters informational needs, but also to respond to human queries with pertinent explanations in natural language.

4 CONCLUSIONS

The courses of action are generated as hypotheses to be used in the process of interpretation of information. Testing the pertinence or validity of hypotheses is accomplished through the process of simulation, by employing a particular subset of the multiresolutional world model. Such simulation or contemplation constitutes a course of action analyses and provide interpretability. The Intelligent Nodes concept will allow computers to serve the warfighters as helpful assistants to assist in accelerating the planning and execution processes by reducing the workload associated with analysis and search for pertinent information.

REFERENCES

[1] S. A. Carey, M. S. Kleiner,. M.R. Hieb, R. Brown, "Standardizing Battle Management Language - A Vital Move Towards the Army Transformation, 2001 Fall Simulation Interoperability Workshop, http://www.sisostds.org/siw/01fall/readlist.htm

[2] Chen P. P, "The Entity-Relationship Model - Toward a Unified View of Data", ACM Transactions on Database Systems, Vol. 1, No 1, March **1976**, pp 9-36

[3] Edward Dawidowicz, Vairzora Jackson, LTC Thomas E. Bryant, Major Martin Adams, " The Right Information and Intelligent Nodes ",8th International Command and Control Research and Technology Symposium, Fort McNair - National Defense University, Washington DC, 17-19 June 2003 http://63.249.165.71/8th_ICCRTS/pdf/105.pdf

[4] **[Eco U. 1990]** Umberto Eco, "The Limits of Interpretation", Indiana University Press; Reprint edition (March 1994), ISBN: 0253208696

[5] John M. McCarthy and Pat Hayes, Some Philosophical Problems from the Standpoint of Artificial Intelligence, Machine Intelligence 4, 1969. It is the basic paper on situation calculus

[6] E. Messina, A. Meystel, "The Challenge of Intelligent Control," Proceedings of the IEEE Int'l Symposium on Intelligent Control, Patras, Greece, 2000

[7] **[Meystel A. 2003]** Alexander M. Meystel, "Multiresolutional Hierarchical Decission Support System" IEEE Transactions on System, Man and Cybernetics, part C: Applications and Reviews, Vol. 33, No 1, February 2003

[8] **[Meystel A., Albus J., 2002]**, Alexander M. Meystel, James S. Albus, "Intelligent System: architecture, design and control", John Wiley and Sons, 2002

[9] **[Morin, A (2003)]**, Alain Morin, "Self-awareness: A neuro-socio-cognitive model of self-awareness with an emphasis on inner speech". Submitted for publication http://www2.mtroyal.ab.ca/~amorin/SAmodel.pdf

[10] **[Saridis G. 2001]** George N. Saridis, "Hierarchically Intelligent Machines", World Scientific Publishing Company, Inc. 2001, **ISBN:** 9810247907

[11] Albert Visser. "An overview of interpretability logic" In M. Kracht, M. de Rijke, and H. Wansing, editors, *Advances in modal logic '96*, pages 307-359. CSLI Publications, Stanford, CA, 1997.